SURFACE ANALYSIS PRECEDING ELECTROFUSION OF THERMOPLASTICS

Cross-Reference to Provisional Application(s)

This application claims the benefit of U.S. Provisional Application No. 60/400,488, filed August 2, 2002, which is incorporated herein in full by this reference.

Background and Summary of the Invention

The invention relates to electrofusion of thermoplastics and, more particularly, to apparatus and method for making a pipe-surface quality determination preceding electrofusion.

Nowadays thermoplastic fittings are commonly fused or welded to thermoplastic pipes by electrofusion technology. Typically the fitting has an embedded conductor coiled inside it for induction heating by an electrofusion processor to accomplish welding to the pipe. It generally is a prerequisite that the involved pipe surface be cleaned and scraped preceding electrofusion. Scraping importantly accomplishes exposing unvarnished and/or fresh plastic for the electrofusion process. Un-scraped or insufficiently scraped pipe exacerbates problems with achieving leak-tight electrofusion welds. In cases of natural gas piping, leaking natural gas is a tremendous hazard.

To date reliance on whether the pipe is sufficiently scraped preceding electrofusion is reliant wholly on the honesty and/or good judgment of the responsible worker.

It is an object of the invention to provide a machine-controlled determination of pipe surface quality preceding electrofusion of thermoplastics in order to eliminate human error.

A number of additional features and objects will be apparent in connection with the following discussion of preferred embodiments and examples.

Brief Description of the Drawings

There are shown in the drawings certain exemplary embodiments of the invention as presently preferred. It should be understood that the invention is not limited to the embodiments disclosed as examples, and is capable of variation within the scope of the appended claims. In the drawings,

FIGURE 1 is an elevational sectional view of two plastic pipe ends butted against one another for permanent joining together by electrofusion technology as known in the prior art, wherein the exterior surfaces of both pipe ends have been cleaned and scraped for a given marginal length extending away from each end such that the scraping exposes unvarnished and/or fresh plastic;

FIGURES 2a, 2b and 2c form a series of views showing an example, prior art, plastic pipe scraper in accordance with U.S. Patent No. 4,663,794—Evans, which is incorporated by reference, wherein:

FIGURE 2a is a side elevational view,

FIGURE 2b is a bottom plan view thereof, and

FIGURE 2c is a side elevational view comparable to FIGURE 2a except showing the scraper in use to accomplish scraping on the exterior of plastic pipe, whereby the scraping process produces a series of spirally formed ridges and valleys proceeding axially along the exterior surface of the pipe;

FIGURES 3a/3b and FIGURE 4 form a series of views showing a non-limiting selection of example electrofusion fittings in accordance with the prior art, wherein:

FIGURE 3a is a side elevational view of tapping-tee fitting and its mating under saddle, which slides on the lips of the tapping-tee in the direction of the reference arrow until limited by stops,

FIGURE 3b is a view in the direction of arrows IIIB-IIIB in FIGURE 3a except in the omitting the under saddle, and

FIGURE 4 is an elevational sectional view comparable to FIGURE 1 except showing an electrofusion coupling fitting slid over the scraped end margins of the abutting pipe ends;

FIGURE 5 is a is a side elevational view comparable to FIGURE 4 except showing the connection of a pair of probe/connectors in accordance with the invention to the opposite terminals of the electrofusion fitting shown by FIGURE 4;

FIGURE 6 is an enlarged detail of the right-side probe in FIGURE 5 (eg., right relative FIGURE 5's perspective) showing a non-contacting probe arrangement in accordance with the invention comprising an emitter (eg., "laser") and "receiver" for sensing quality of pipe surface matters such as the local presence or absence of sufficient scraping (or skinning) on the pipe exterior;

FIGURE 7 is a perspective view of an electrofusion processor modified in accordance with the invention as more particularly described below;

FIGURE 8 is a is schematic view of a preferred embodiment of the invention for utilizing the results of surface analysis preceding electrofusion of thermoplastics in accordance with the invention;

FIGURE 9 is a flowchart showing a method in accordance with the invention for determining a particular "reference signal" as denominated in FIGURE 8;

FIGURE 10 is a flowchart showing a method in accordance with the invention for determining passing or failing pipe surface quality preceding electrofusion welding of thermoplastics in accordance with the prior art; and

FIGURE 11 is an elevational sectional view comparable to FIGURE 4 except showing successful completion of electrofusion welding of the pipe ends and coupling.

Detailed Description of the Preferred Embodiments

The invention relates to apparatus and methods as more particularly described below for making machine-controlled determination(s) of pipe surface quality preceding electrofusion of thermoplastics, and in order to promote elimination of human error.

By way of background, briefly, electrofusion includes at least the practice of mating plastic parts by the fusion achieved from the heat developed in hot-wire coil(s) embedded in one or the other of the parts (eg., typically embedded in a fitting). FIGURE 1 shows the ends of two plastic pipe ends butted against one another in preparation for permanent joining together by electrofusion technology as known in the prior art (although that will require a 'coupling' fitting as shown by, eg., FIGURE 4). The exterior surfaces of both pipe ends have been cleaned and/or scraped (eg., skinned) for a given marginal length extending away from each end such that the scraping (or skinning) exposes newly-exposed plastic. FIGURES 2a, 2b and 2c are a series of views showing an example, prior art, plastic pipe scraper and in accordance with U.S. Patent No. 4,663,794—Evans.

In general, raw or un-scraped (un-skinned) pipe stock is procured with a varnished or otherwise smooth finish that is unsuitable for electrofusion process(es) while in that raw or un-scraped (un-skinned) condition. That is, there is an unacceptable likelihood that an electrofusion joint will fail quality standards if obtained by plastic parts having any surface varnish or dirt if not oxidation or contamination or OED printing thereon. Hence it has long been a practice in the industry to scrape off a skin- or surface-layer of the pipe in order to expose fresh or clean plastic which indeed is suitable for electrofusion process(es). Scrapers typically have a blade that is about ⅜-inch (~ 10 mm) wide and formed with about twelve shallow teeth across such width such that as a result the scraper might leave about thirty-two lines per inch (~ twelve lines per cm) of helically-formed ridges (alternated of course by valleys) along the axial extension of the exterior surface of the pipe. The prior art scrapers are arranged to auto-advance themselves helically along the axis of the pipe while being turned in complete rotations so that the last furrow left behind by the trailing tooth of the blade plows through the plastic skin more or less accurately parallel and properly spaced

relative to the leading furrow cut or plowed one-rotation previously by the leading tooth. In other words, a scraped-section of pipe appears to be formed with a continuous screw thread, having a coarseness at about thirty-two lines per inch ($\sim$twelve lines per cm), although relatively finer and much more coarser teeth arrangement are also known in the art.

Additionally, the scraping typically produces a surface roughness of between about 200 microns ($\sim {}^{5}/1000^{\text{ths}}$ mm) and 500 microns ($\sim {}^{13}/1000^{\text{ths}}$ mm). In contrast, un-scraped sections of the pipe typically exhibit a much smoother finish, measuring for example at about 30 microns (very approximately $\sim {}^{1}/1000^{\text{ths}}$ mm), which despite being smoother is structurally disordered and not nearly as structurally ordered as scraped pipe, such structural ordering being (as said) in the form of, eg., screw thread.

FIGURES 3a and 3b together show one example of a prior art electrofusion fitting, and that being a tapping-tee fitting. FIGURE 3a shows the tapping tee fitting situated on a section of scraped pipe, as prior to electrofusion. FIGURE 3a also shows that the tapping-tee fitting has a mating under saddle, which slides on the lips of the tapping-tee in the direction of the reference arrow until limited by stops. The under saddle is utilized predominantly for temporary clamping purposes only. As soon as the electrofusion weld is completed, the under saddle might be optionally removed as needless although it is typical to leave it in place. If the under saddle were removed after welding, then FIGURE 3b shows an axial view (ie., in the direction of arrows IIIB-IIIB in FIGURE 3a) of how that would appear.

FIGURE 4 shows a further example of an electrofusion fitting in accordance with the prior art, this more particularly being a coupling fitting. Coupling fittings receive insertion of the scraped end margins of a pair of abutting pipe ends, such as comparably shown previously in FIGURE 1. In FIGURE 4, the fitting has a barrel section having an inner surface formed with an embedded hot-wire coil conductor wound in a helix around the barrel section and terminating in opposite terminals. To weld, the terminals are connected to connectors (not shown but see, eg., what is denominated as "C" in FIGURE 7) of an electrofusion processor (again not shown in this view but see, eg., FIGURE 7). The

electrofusion processor supplies power to the terminals through the connectors. How much power, and by what profile of power-against-time, is a matter which is highly fitting-specific. Notwithstanding, fitting manufactures widely disseminate such specifications for their fittings and they even code their fittings accordingly, typically by way of a bar code. Prior art electrofusion processors (see for comparison, eg., FIGURE 7) include readers of such bar codes by way of for example and without limitation a bar code wand (not shown in FIGURE 4 but see, eg., what is denominated as "W" in FIGURE 7) in order to search through their memory fir what power-against-time profiles are expected, and supply such. The fitting in FIGURE 4 furthermore includes a pair of visual ports, which are alongside the pair of terminals respectively. After the fitting has been fused welded to form the pipe connection, the visual ports afford an operator opportunity to visually inspect the success (or not) of the weld. The foregoing are matters of the prior art.

FIGURE 5 is a view comparable to FIGURE 4 except showing the connection of a pair connectors in accordance with the invention to the pair of opposite terminals of the electrofusion fitting of FIGURE 4. The inventive connectors generally combine conventional aspects of supplying power to the terminals along with more particularly a pair of probes in accordance with the invention for making an inventive surface-analysis determination precedent to electrofusion welding.

FIGURE 6 shows better one preferred arrangement for the probe(s) in accordance with the invention. The operative principle comprises measuring the reflection, or more accurately the change or loss of such, of an emitted signal as detected or collected by one or more signal receivers. Accordingly, the invention preferably operates on the basis of non-contact techniques.

As FIGURE 6 more particularly shows, a signal emitter comprises a laser source as, for example and without limitation, a diode laser operating on a six-hundred nanometer wavelength (eg., visible red light). The emission receiver or collector optionally comprises an infrared/photo-transistor although alternatively a photo-diode works as well, and a photo-

resistor presents another option still. One such group of usable devices include without limitation CdS cells (and as indicated in FIGURE 8).

It is preferred to aim the signal emitter at as shallow angle-of-attack as possible, perpendicular to the ridges of the scraped (or skinned) surface. To date the shallowest angle experimented with has been at 15° although it is believed that, if such can be constructed, half that angle would work better still. FIGURE 6 shows that a patch of the scraped surface, as illustrated by a dot-dash line, is impinged by the emitted signal. This patch, rather than being an infinitesimally small point, actually has some size. The impinged patch has an ovate shape (if viewed from above) and impinges upon two to five or more lines of ridges. Arranging things for a shallower angle is better because correspondingly that means more lines of ridges will obstruct or interfere with the 'clean' reflection of the emitted signal.

There are impediments to producing a probe with as shallow angle as desired, and these impediments relate to physical problems when working at such a miniature scale. It is preferred to overcome such impediments by folding the signal with one or more mirrors at least for the purpose of locating both the emitter and collector on the outboard side of the probe where there is more physical space to mount such.

FIGURE 7 shows an electrofusion processor that is modified in accordance with the invention to include circuitry and controls to obtain such functionality as machine-controlled determination of pipe surface quality preceding electrofusion of thermoplastics. The electrofusion processor comprises an input line cord "I," output leads "O," output lead connectors "C," bar-code wand "W," and various connector adaptors not specifically referenced and partially covered by reference letter "W." The input line cord "I" plugs into something as public utility power which in this country runs at about one-hundred and twenty VAC line voltage. The electrofusion processor is configured (or programmed) for stepping through the functions of, among other functions, energizing the probe(s) and analyzing the signal(s) obtained thereby in order to make a quality determination if the pipe surface(s) has(ve) been sufficiently scraped (or skinned or otherwise made suitable). This functionality is more particularly shown in connection with FIGURES 8 and 9. Other

functionality which is extra for the purpose includes without limitation data-logging functions which record and store operator functions against a time and date stamp in order to allow '*ad hoc*' auditing of operator honesty and/or integrity. It is an object of the invention that, in cases of a failing surface-analysis determination, the electrofusion processor is aborted or disabled from any chance at welding until a passing surface-analysis determination is obtained. Presumptively a passing surface-analysis determination can only practicably be obtained by an operator performing a reasonably timely calibration and then, after that, obtaining a very recent passing surface-analysis prior determination to a fusion operation. Instances of failing surface-analysis determination to date are presumptively/preferably overcome by an operator (or worker) disassembling the fitting and pipe(s) in order to scrape or re-scrape (skin or re-skin or the like) the involved pipe surface(s) for a succeeding chance to obtain a passing surface-analysis determination.

FIGURE 8 is a is schematic view of a preferred embodiment of the invention for utilizing the results of surface analysis preceding electrofusion of thermoplastics in order to determine passing or failing surface-analysis determination. The receiver is shown receiving the received signal, wherein FIGURE 6 shows a preferred arrangement for positioning a signal receiver in accordance with the invention relative to a surface to-be-analyzed and the source of such signal, a signal emitter in accordance with the invention. The receiver provides its own output-signal corresponding to the received signal. The receiver's output signal is fed to a comparator (eg., 'comparison operator' or like op-amp) which compares the receiver's output signal to a reference signal. At present it is preferred if the comparator provides an output which signifies "pass" or "fail" although it is more preferred still if the comparator outputs a range of values corresponding to a range of quality findings (eg., ranging from an upper extreme of fairly superior to a lower extreme of fairly inferior). The output of the comparator is fed to a control system, as shown generically in FIGURE 8. The control system operates to achieve several functions. One, the control system disables the operability of the weld function of the electrofusion processor until a timely "pass" surface-analysis is achieved. Another, the control system provides a recordable activity for

the data-logger to record so that a relatively permanent record is made of the "pass, "fail" and/or 'degree' (or other) determination for audit purposes. Additionally, the control system provides the operator with one or more feedback signals so that the operator can act to correct the situation accordingly.

Preferred at present and due to changing preference in the future, it is preferred to compare the received (or measured) signal against a reference signal in order to make a "pass" or "fail" (or in-between quality) surface-analysis determination in accordance with the invention. It is known, however, in fields of industry outside the invention to utilize multiple metrics and/or criteria to make a surface-analysis evaluation, such as disclosed by and without limitation Lasercheck® gauge of the Optical Dimensions Co., of Lake Forest, California. Ideally it might be desirable to utilize the most advanced technology available to make a most complete surface-analysis determination. But in the real world of protecting against human error in electrofusion practice it is more realistic to practice technology which is highly competent though not the most advanced for the purposes of making a "pass" or "fail" (or in-between) surface-analysis determination precedent to electrofusion. It is believed that utilizing highly-competent in contrast to the most-advanced technology is more practical when better opportunity for advancing the objects of the invention are to be obtained from analyzing a larger area/circumference of the pipe(s).

FIGURE 9 is a flowchart showing a methodology in accordance with the invention for determining a particular "reference signal" as denominated in FIGURE 8. FIGURE 9 represents what might be alternatively referred to as a 'set-up' or a 'calibration' process. An operator at the job-site fetches or acquires a sample piece of the pipe(s) to-be-welded. The object is to determine what signal the un-scraped (or un-skinned or otherwise un-cleaned) pipe provides under local conditions. Local conditions include color and type of pipe to-be-welded as well as the ambient light (in spite of shielding or hooded-enclosures to block out ambient light). Preferably this calibration or set-up cycle would likewise be logged by the data-recorder for audit purposes to determine irregularities and the like.

Step one involves the operator procuring a sample of the un-scraped (or un-skinned or insufficiently cleaned) pipe of the color and type to-be-welded before the welding process(es) are to be attempted. It is preferred if this step is done often. For example, a work day which will involve a lot of welding of the same type and color of pipe deserves calibration at least at the beginning of the day. Indeed the calibration process might best be performed several times during a day as there are likely changing circumstances with the quality of the pipe or else the amount of leakage of ambient light. In contrast, with reference to FIGURE 6, the diminishment of the received signal as compared to a reference of un-scraped (or un-skinned or insufficiently cleaned) pipe against scraped (or its corollary sufficiently skinned or cleaned) pipe is ordinarily substantial:-- particularly for yellow and white pipe, yellow pipe being more common in natural gas piping.

A succeeding step involves inserting one or more samples of un-scraped (or insufficiently skinned or cleaned) pipe under the probes to obtain a reference value. Perhaps one sample is sufficient to obtain the reference value. Better yet is if the operator subjects several samples to the work of the probes to provide several individual reference values, and with which the processor's control circuitry analyzes for determining a 'statistical' reference value. FIGURE 9 shows a manual way of determining individual reference values, as by an operator manually tuning a dial as to a variable resistor (or potentiometer) or the like until such activity finds a given level of diminishment of the received signal in comparison to the emitted signal. The foregoing assumes the circuitry is measuring signal strength.

Ultimately, by means of the foregoing, the operator establishes a reference value which compares favorably to what un-scraped (or insufficiently skinned or cleaned) pipe looks like.

FIGURE 10 is a flowchart showing a further methodology in accordance with the invention for determining passing or failing pipe surface quality preceding electrofusion welding. The presumptive input or starting materials (and apparatus) include an electrofusion processor or probe-operating/signal-processing system in accordance with the invention, a fitting and one or more pipes depending on whether it is a single pipe to-be-

welded to (eg, in cases of a tapping-tee fitting) or more (eg., in cases of a coupling fitting). Step one preferably comprises the original attempt to satisfactorily scrape (or skin or clean) the involved pipe section(s) prior to welding. Step two presumptively comprises assembling the fitting where it belongs. The succeeding steps comprise variously inputting to the electrofusion processor the particulars of the particular fitting:-- nowadays that being most popularly accomplished by bar-code coding affixed to the fitting in combination with equipping the electrofusion processor with a bar-code reader (eg., "W" in FIGURE 7). It is presumed that the fitting's welding particulars will be a relevant factor in surface-analysis evaluation, but then perhaps not. What is presumptively most relevant is whether the relevant pipe section(s) has(have) been properly scraped (or otherwise skinned or cleaned).

Provided that the fitting is properly disposed on the presumptively-properly scraped (or skinned or cleaned) pipe section(s), a preferred succeeding step is to energize the probe(s). It is preferred that the electrofusion processor be disabled from providing welding-power to the fitting's terminals unless as a condition precedent the electrofusion processor is enabled to do so by the probe control circuitry. Therefore, energizing the probes for the first time affords the first opportunity to get an "operative" feedback signal. In contrast, if a "fail" (or "abort" or "disable") feedback signal is obtained, the operator is faced with several choices. Perhaps the fitting was improperly aligned over properly scraped (or skinned or cleaned) pipe section. Re-alignment might solve the problem. Perhaps otherwise, the pipe section(s) is(are) indeed insufficiently scraped (or skinned or cleaned), and therefor the operator's only practical choice for remedy is to disassemble and re-clean (eg., scrape or skin) the involved pipe section as whole.

Such is done iteratively until ultimately a "pass" (or the like) signal is obtained from the probe(s)'s processing/control circuitry. Given satisfaction of the foregoing condition(s), the probe(s)'s processing/control circuitry enables (eg., no longer aborts or disables) the electrofusion processor's weld functions (eg., the power-supply feed to the terminals). Therefore a better likelihood of a satisfactory weld in accordance with OEM prescriptions is much more likely obtained. The invention offers the prospect of negating human error

better than nowadays achieved by previously practiced practices in the field of electrofusion of thermoplastics.

FIGURE 11 is sectional view comparable to FIGURE 4 except showing successful completion of electrofusion welding of the pipe ends and coupling. It is an object of the invention to promote a better likelihood of achieving satisfactory welds by a machine "checking" of the condition of things precedent before welding is attempted, as well as by providing a data log of such, for auditing purposes, not as much for back-tracking to identify operators lacking integrity but more for the benign purpose of reminding operators persistently that there is log of their operations. To be abstract for a moment, a popular definition of integrity is not only that one would do as one would want for themselves but alternatively that one would "do" with the thought that someone else is watching over one's shoulder. Every action will be public, or at least exposed in the end. The data logging functions of the invention promote the concept of that "someone" else is indeed watching over one's shoulder. It's not so much an object of the invention to create an onerous "big brother," but that given good people who work as operators, who are nevertheless pressured by productivity pressures, better it is to promote good work ethics for the larger good of public welfare or safety than to rush a job and endanger such for sake of meeting productivity targets. Given that many of the many of these electrofusion welds are made in natural gas pipelines, the stakes are paramount. It is not so much a matter of assuring no contractor forsakes its/his responsibility but that no contractor endangers the public needlessly beyond what are locally-stated or more broadly-codified acceptable criteria for constructing electrofusion-formed piping systems.

The invention having been disclosed in connection with the foregoing variations and examples, additional variations will now be apparent to persons skilled in the art. The invention is not intended to be limited to the variations specifically mentioned, and accordingly reference should be made to the appended claims rather than the foregoing discussion of preferred examples, to assess the scope of the invention in which exclusive rights are claimed.